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## Management of hydrilla with insect biological control agents

by

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Since the introduction of hydrilla (*Hydrilla verticillata* (L. fil.) Royle) to the United States, in Florida in the 1950s, its spread has been rapid. By 1961 it was considered a serious nuisance plant throughout central and south Florida (Haller 1978). Hydrilla spread to the neighboring south-eastern states, reaching Louisiana by 1973 and Texas by 1974. It was discovered in California in 1976 and, later, along the eastern U.S. seaboard, with populations found in North Carolina in 1979 and in Delaware in 1981. During 1982, a monoecious biotype was reported from the Potomac River, near Washington, DC.

In recent years, managers and researchers have begun a search for alternatives to conventional treatments such as herbicides. One alternative management strategy is the use of host-specific biological control agents. This research initiative was officially begun in 1980 when the U.S. Department of Agriculture, Agricultural Research Service (USDA, ARS), and the U.S. Army Corps of Engineers entered into an informal cooperative

effort to identify and develop bio-control agents of hydrilla.

To date, this effort has resulted in the release of four insect biocontrol agents in the United States for managing hydrilla. This article summarizes the life histories and biologies of these four insects, discusses their status and predicted impact, and describes the future direction of the hydrilla biocontrol program.

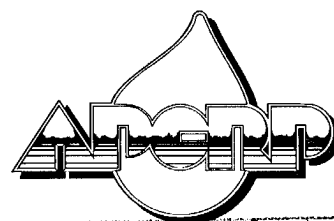
### Preliminary studies

The first step in using biological control agents for hydrilla management was to delimit regions of the world that warranted further study and to identify already known bio-control agents for hydrilla. This was accomplished by conducting extensive literature reviews and initial overseas surveys. World-wide faunal surveys resulted in the selection of hydrilla biocontrol agents from various tropical and subtropical regions (Balciunas 1982). The first two agents selected for further testing, obtained from India, included a tuber-feeding weevil, *Bagous affinis*, and the leaf-mining fly

*Hydrellia pakistanae*. These insects had originally been discovered in Pakistan during the early 1970s as part of an excess foreign currency project (Public Law 480) (Baloch, Sana-Ullah, and Ghani 1980). Both of these agents were eventually imported into U.S. quarantine for further host-specificity testing (Buckingham 1988) and were subsequently released at sites in Florida beginning in 1987 (Center 1989).

Following these initial attempts with insects from India, surveys of potential agents were also begun in Australia. Six potential agents were identified (Balciunas and Center 1981). Of these, four insects were introduced into U.S. quarantine for further host-specificity testing. The leaf-mining fly *Hydrellia balciunasi* and the Australian stem weevil, *Bagous hydrillae*, were subsequently released into the United States in 1989 and 1991, respectively.

The remaining four species identified in the Australian surveys were stream-dwelling moths, important for their ability to feed and damage hydrilla under higher water velocities. These species included *Strepsinoma repititalis*, *Nymphula dicentra*, *Aulacodes siennata*, and *Nymphula eromenalis*. The latter two species were studied briefly in quarantine (Bennett 1993,



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Buckingham 1994). Unfortunately, these species fed on a wide variety of plant species and were therefore dropped from further consideration.

More detailed information on the four biocontrol agents released in the United States for management of hydrilla is provided below.

## Hydrilla tuber-feeding weevil

### Biology/description

*Bagous affinis* is a small (3- to 4-millimeter-long) brown and black mottled weevil (Figure 1a) that originates from India and Pakistan. It was first introduced into the United States for hydrilla management in 1987. The mottled appearance comes from patches of lighter brown and beige coloration covering the body.

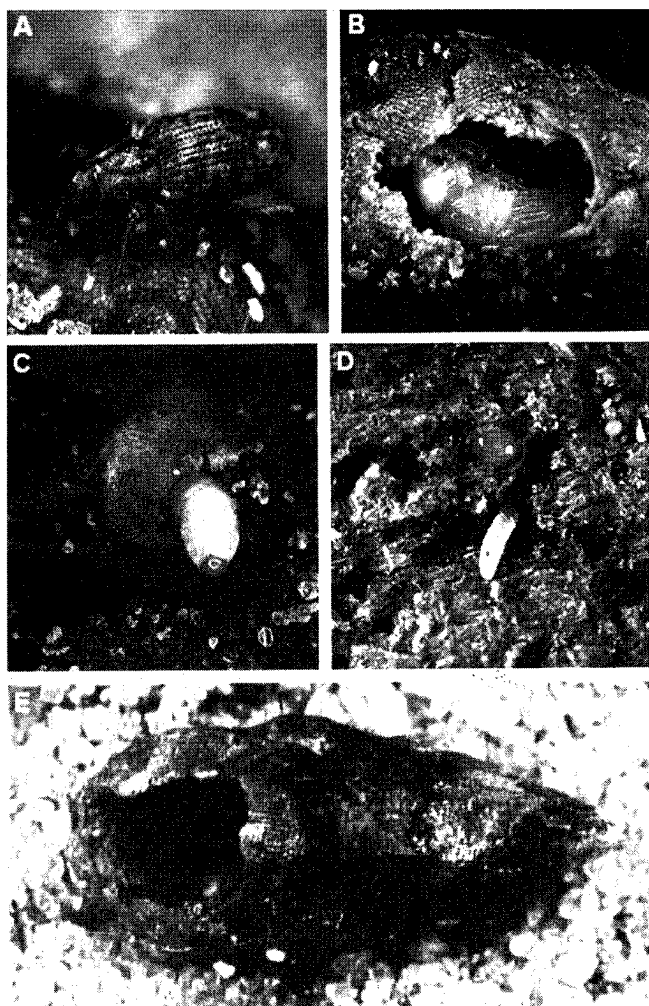


Figure 1. Life stages and damage of *Bagous affinis* (hydrilla tuber-feeding weevil): A, adult; B, pupa within damaged tuber; C, late instar larva feeding within tuber; D, egg and first instar larva; and E, close-up of damaged tuber

Adults feed on a variety of hydrilla tissues, including leaves, stems, turions, and tubers, but appear to prefer stem tissues. The adults deposit eggs in several different substrates in the laboratory, but most often select water-logged wood or other similar types of organic material (Figure 1d). Eggs are not deposited on submersed material of any kind. Eggs are roughly spherical with a creamy white coloration. Females are known to produce upwards of 650 eggs throughout their active reproductive period.

This species is adapted to climatic conditions consisting of distinct wet/dry conditions, as found during the monsoon season that occurs in many portions of Indonesia. During the dry season, when ponds and other similar water bodies begin to dry, females deposit eggs and larvae emerge and burrow into the exposed sediment in search of buried tubers (Figure 1d). Once located, the larvae feed and burrow into the tubers, essentially destroying their regenerative properties.

Larvae typically pupate within the damaged tuber, but have been observed to pupate in nearby moist wood (Figures 1b and 1c). Total development time is 18 to 29 days.

### Status

The first release of *B. affinis* occurred in 1987 at Lake Tohopekaliga, Florida. Since that initial release, over 11,000 individuals of various life stages have been introduced at 11 south Florida locations and one Texas site, in over 28 separate releases (Grodowitz, Center, and Snoddy 1995). While evidence of establishment (that is, insect-damaged tubers) was observed from sites on Rodman Reservoir near Gainesville, FL, during a drawdown, the increase in water-level eliminated any evidence of this species from the area (Buckingham 1990). Such increases in water level have occurred at other *B. affinis* release sites. Because of *B. affinis*' requirement for extended dewatered conditions, it appears to have only limited potential for use as a biocontrol agent in the United States. Such natural drawdowns occur only sporadically in the southeastern United States.

In California, however, water levels in many of the canals and lakes can be controlled to a large extent, thereby allowing extended dewatered conditions to prevail. Because of such water-level control, *B. affinis* has been released at several locations in California since 1993 (Godfrey and others 1994). Preliminary results have indicated successful overwintering of this species at several northern California sites. Introductions in California continued through 1994 but have been stopped.

## Future plans

As discussed, natural drawdowns are rarely seen in most of the U.S. hydrilla range. However, one site has been identified in southern Texas that periodically undergoes natural dewatering due to natural decreases in area rainfall. Choke Canyon Reservoir undergoes periods of slow reductions in water levels that are related to decreases in area rainfall and the continual pumping of water from the reservoir to locations downstream. This allows for extended periods during which sediment is exposed, allowing for tuber access by *B. affinis*. Recent introductions of *B. affinis* have been made at Choke Canyon, and releases will be continuing in the future.

## Leaf-mining flies

### Biology/description

Both species of introduced leaf-mining flies, *H. pakistanae* and *H. balciunasi*, are highly similar in appearance (Figures 2a and 3a) and in biology to one another as well as to several commonly collected *Hydrellia* native to the United States. The adults are small, about 2 millimeters in length, and can be found resting on emergent plant species in the vicinity of hydrilla infestations. Adult *Hydrellia* superficially resemble many species of small gnats that are often associated with aquatic systems. One easily observable difference is that they appear to hop from one resting place to another instead of actually flying.

Adult *Hydrellia* are relatively difficult to identify in comparison to other species of insects introduced for the management of hydrilla. The difficulty arises because of their small size, lack of any obvious distinguishing characters, their similarity to native *Hydrellia*, and the required use of external reproductive characters for identification. However, with some practice and use of a good grade of dissecting microscope, identification can be made by nontechnical personnel. An excellent reference to the systematics and ecology of the nearctic *Hydrellia* is a monograph written by Dr. D. L. Deonier (Deonier 1971).

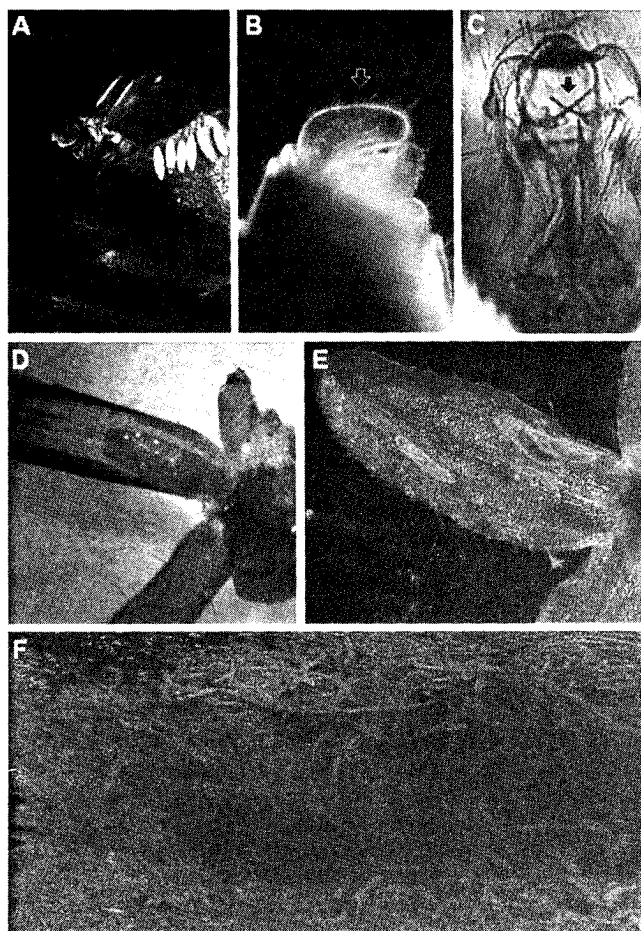
Males of both species (*Hydrellia balciunasi* and *H. pakistanae*) can be distinguished from each other and other commonly collected native species by several different characters, including the length of the thorax in comparison to the abdomen length, presence of crossed or cruciate macrochaetae, and shape of the macrochaetae.

The abdomen in both species of introduced *Hydrellia* is relatively short and roughly the same size as the thorax. In contrast, all commonly encountered native

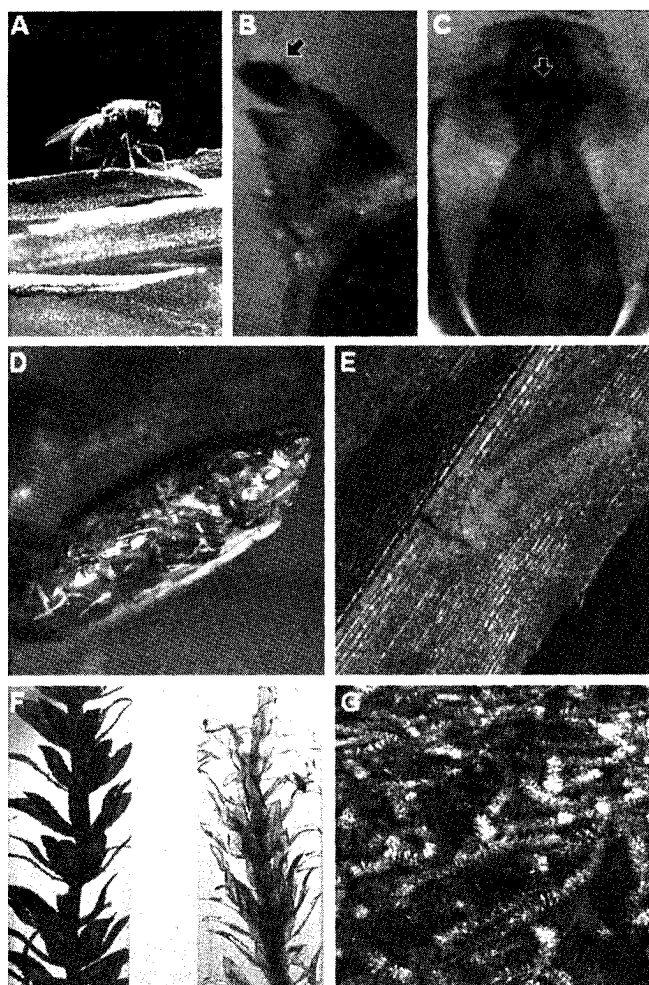
*Hydrellia* species have abdomens that are 1.5 to 2 times longer than the thorax.

The macrochaetae are small hairlike structures associated with the external reproductive structures that are responsible for holding the female in place during copulation. In both species of introduced *Hydrellia*, the macrochaetae are crossed or cruciate (Figures 2c and 3c).

The most important character for distinguishing *H. balciunasi* from *H. pakistanae* is the shape and size of the macrochaetae. The macrochaetae in *H. balciunasi* are large and flattened at the distal ends (that is, the end farthest from where the macrochaetae attach to the body) (Figure 3c), while in *H. pakistanae* and the macrochaetae are smaller and distinctly needle-shaped (Figure 2c).



**Figure 2.** Life stages and damage of *Hydrellia pakistanae* (Asian hydrilla leaf-mining fly): A, adult; B, close-up of female genitalia, showing characteristic L-shape of cerci; C, close-up of male genitalia (ventral side), showing characteristic crossed macrochaetae which are needlelike; D, pupa; E, larvae and associated leaf-mining damage; and F, characteristic field damage (note the sinking of the hydrilla by its loss of buoyancy)



**Figure 3.** Life stages and damage of *Hydrellia balciunasi* (Australian leaf-mining fly): **A**, adult; **B**, close-up of female genitalia, showing characteristic diamond shape of cerci; **C**, close-up of male genitalia (ventral side), showing characteristic crossed macrochaetae which are larger than those of *H. pakistanae*; **D**, pupa; **E**, larva and associated damage; **F**, feeding damage (right) compared to control (left); and **G**, field damage

Female *Hydrellia* are also distinguished from native and other introduced *Hydrellia* by the morphology of the external genitalia. In females the shape of the cerci is one of the most important. In *H. balciunasi* the cerci are roughly triangular, arrow- or diamond-shaped (Figure 3b) compared to L-shaped, as in *H. pakistanae* (Figure 2b). Commonly collected native *Hydrellia* have cerci that vary considerably from these shapes.

Eggs of both *H. balciunasi* and *H. pakistanae* are deposited near the water surface, in protected places on emergent aquatic vegetation near hydrilla infestations (Figure 2a). Females lay eggs singly, with each female depositing more than 100 eggs during her reproductive period. Eggs hatch in 3 to 4 days depending on temperature.

Larvae emerge from the eggs and crawl down into the water in search of hydrilla. Larvae bore into the hydrilla leaf through the outer leaf cuticle. They tunnel or mine the leaves, feeding and destroying about 9 to 12 leaves during the three larval stages (Figures 2e and 3e). Leaves on which the larvae have fed appear transparent, with only a small rim of green tissue remaining in the outer margins of the leaf (Figure 3f). From a distance the hydrilla appears to be highly bleached or solarized, with distinct areas of the stem containing leaves that are lighter in coloration (Figure 3g). In the presence of high amounts of damage (>40 percent of the leaves damaged), the hydrilla apparently loses its ability to float and begins to sink, leaving large irregularly shaped holes in the mat (Figure 2f).

Third instar larvae pierce the stem tissues with two needlelike projections and pupate while attached to the stem. It is believed that the attachment to the stem allows the pupae to obtain oxygen from internal vascular spaces. The pupae are housed within a protective case known as the puparium, which is formed from the hardened larval cuticle (Figures 2d and 3d). The pupae are roughly cigar-shaped and appear similar to axillary leaf buds. The pupal stage lasts from 6 to 15 days, after which the emerging adult floats to the surface in an air bubble. Total development time is 20 to 29 days.

### **Status, *H. pakistanae***

*Hydrellia pakistanae* was first released in Florida during fall 1987. Since then, *H. pakistanae* has been released in 35 locations in five southeastern states (Florida, Georgia, Alabama, Louisiana, and Texas). The majority of releases have been made in Florida.

Verifiable establishment has been high, with populations of *H. pakistanae* occurring throughout southern Florida and as far west as Lake Seminole, a large lake located on the Georgia/Florida border. In the rest of the United States, *H. pakistanae* populations can be found north to Muscle Shoals, AL, and west to Coletto Creek Reservoir (approximately 160 kilometers north of Corpus Christi, TX).

Populations of *H. pakistanae* can develop rapidly. This is evidenced by populations reaching as high as 6,000 immatures/kilogram of hydrilla in just 60 days after the termination of releases in ponds at the Muscle Shoals biocontrol pond research facility. Such a high population level correlates with damaged leaves at a rate close to 60 percent. Damage of such magnitude causes substantial changes to the status of the hydrilla, causing large holes to develop in the mat where the plants apparently lose buoyancy and sink (Figure 2f). Such changes and sinking of the hydrilla have been observed at several sites in Florida and Alabama.

## Status, *H. balciunasi*

*Hydrellia balciunasi* has proven to be more difficult to establish as compared to *H. pakistanae*. Even with repeated releases in Florida and Texas of close to 300,000 individuals at nine locations, only two sites in the United States have long-term established populations (Sheldon Reservoir and Huntsville State Park, Texas). At both of these sites, population levels of *H. balciunasi* have remained at consistently low levels and have never exceeded 1,500 immatures/kilogram on any sampling date.

## Future plans

Releases of *H. pakistanae* will continue at various locations in the United States. In the immediate future, the releases will be concentrated in Texas, with only limited releases in more northern locations such as South and North Carolina. Recently, another strain of *H. pakistanae*, which was collected from temperate regions in China, has been introduced. It is assumed that this strain is more tolerate of colder conditions since it was collected from Beijing. To date, only limited success has been noted with rearing this strain for large-scale releases. New individuals were collected from China during summer 1995, and progeny from these individuals will be used to start another laboratory colony. These will be used for future releases in the more temperate regions of the United States.

## Australian stem-feeding weevil

### Biology/description

*Bagous hydrillae*, the hydrilla stem-feeding weevil, is a small (3-to 4-millimeter), dark brown weevil first introduced into the United States in 1991 (Figure 4a). It is native to Australia, where it is frequently found in association with hydrilla, which has been fragmented and subsequently stranded on the shoreline.

Adults have two to four light-colored spots on the posterior portion of the elytra (wing covers). Adults feed externally on hydrilla stems and leaves, producing distinct notches in hydrilla stem and roundish holes in the leaves. Adults can be collected from stranded hydrilla on the shoreline, as well as from submersed plant material. Newly emerged females do not lay eggs immediately, but require a 3- to 10-day pre-ovipositional period during which their ovaries mature.

Eggs are laid within the stem in small holes near the leaf nodes (that is, the attachment point of the leaves) (Figure 4e). The larvae emerge in 3 to 4 days after oviposition and feed throughout the internal stem tissue

(Figures 4c and 4d). Each female deposits about three eggs per day and up to 300 eggs (average 100) during her lifetime.

The three larval instars burrow and feed within the stems, creating long galleries. These galleries become necrotic (decayed), eventually causing the stem around the damaged area to appear blackened externally. The stems weaken at these larval feeding points and at the notches caused by adult feeding. According to Balciunas and Purcell (1991), this feeding action by the larvae causes the plants to fragment and the pieces to float to shore by wind and wave action. This provides a mechanism for the larvae to reach drier conditions (the shore), in order to pupate. An alternative hypothesis is that this species is adapted to areas where there is a distinct wet/dry period. During periods of high rainfall, the adults and larvae

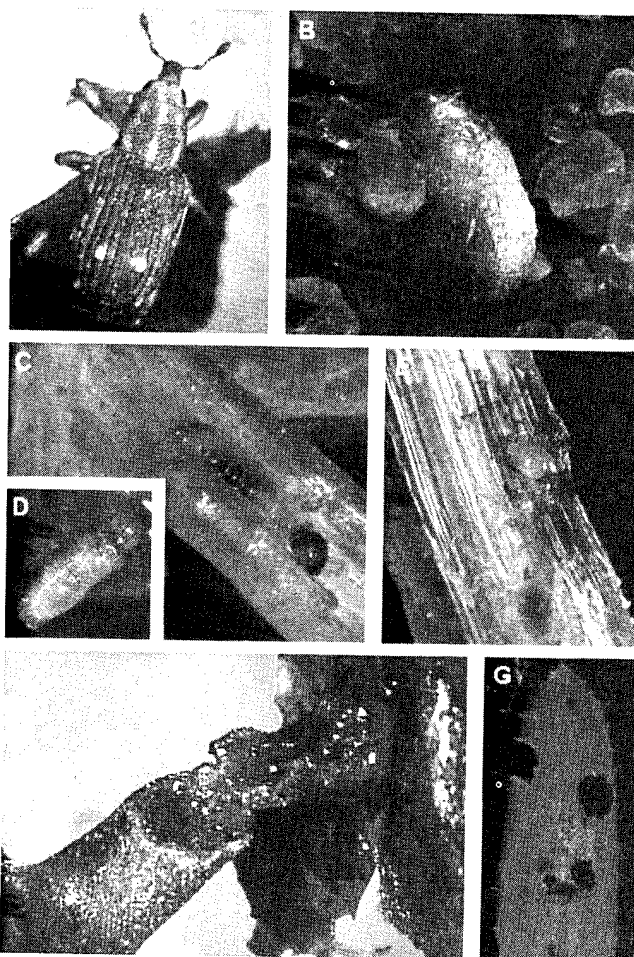


Figure 4. Life stages and damage of *Bagous hydrillae* (hydrilla stem-feeding weevil): A, adult; B, pupa; C, larva and its feeding gallery, found within a hydrilla stem; D, early instar larva; E, egg that has been removed from within stem tissue; F, adult feeding damage on stem nodes; and G, adult feeding damage on hydrilla leaves



reside mainly within submersed hydrilla and little, if any, pupation occurs. However, during periods of extreme drying, pupation increases as the larvae are now able to reach the sediment as the water evaporation rates. In any case, the larval developmental period is brief, requiring only about 6 to 8 days at 25 °C.

The fully grown larvae pupate (Figure 4b) within the stranded hydrilla or in the underlying soil to complete their developmental cycle. The adults emerge from pupation in about 4 days. Total generation time required for an egg to transform into a mature egg-laying female is about 2 to 3 weeks.

While large-scale damage for this species has not been observed in this country, researchers in Australia have indicated that larval and adult feeding causes the plants to have a mowed appearance by the removal of hydrilla from the surface to a depth of about 100 centimeters.

### Status

Since 1991 over 300,000 *B. hydrillae* have been released at sites in Florida, Alabama, Georgia, and Texas. To date, no long-term establishment has been observed at any location. However, recent releases at sites in southern Texas near Corpus Christi look more promising. Choke Canyon Reservoir undergoes periodic drying due to decreases in local rainfall, as mentioned in the discussion of *B. affinis*. Since 1993 significant reductions in water level (upwards of 3 meters) have occurred, causing massive quantities of hydrilla to be stranded. With the release of more than 40,000 *B. hydrillae* since the summer of 1993, collections at various locations on Choke Canyon Reservoir have revealed the presence of the stem-boring weevil at several sites. The presence of a native stem borer, *Bagous restrictus*, confounds the situation somewhat. Although releases are continuing, the presence of *B. hydrillae* for extended periods indicates that tentative establishment has occurred.

### Future plans

Continued monitoring and releases of *B. hydrillae* at this and similar sites are planned.

### Summary

The use of biocontrol for hydrilla management looks especially promising. Since 1987, four insect agents have been introduced in several southeastern states. Of these four species, *H. pakistanae* is established in four states, with populations increasing rapidly in many areas. *Hydrellia balciunasi* is established at only two locations in Texas. Tentative establishment has been noted for the stem-feeding weevil at one site

in south-central Texas. One of the first agents released, *Hydrellia pakistanae*, has undergone significant range expansion, and significant declines in hydrilla have been correlated with increased population numbers of this agent. With the anticipated range expansion and population number buildup over time, continued hydrilla impact is expected.

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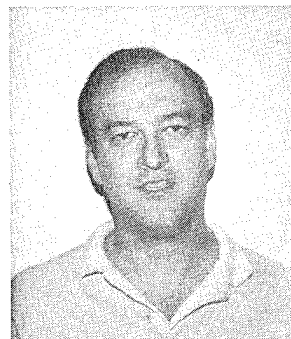
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